CEMENT

AND

CEMENT MANUFACTURE

ISSUED MONTHLY AS A SUPPLEMENT TO
"CONCRETE & CONSTRUCTIONAL ENGINEERING"

VOL. I. No. 1.

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ISSUED AS A SUPPLEMENT TO "CONCRETE & CONSTRUCTIONAL ENGINEERING"
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"Cement and Cement Manufacture."

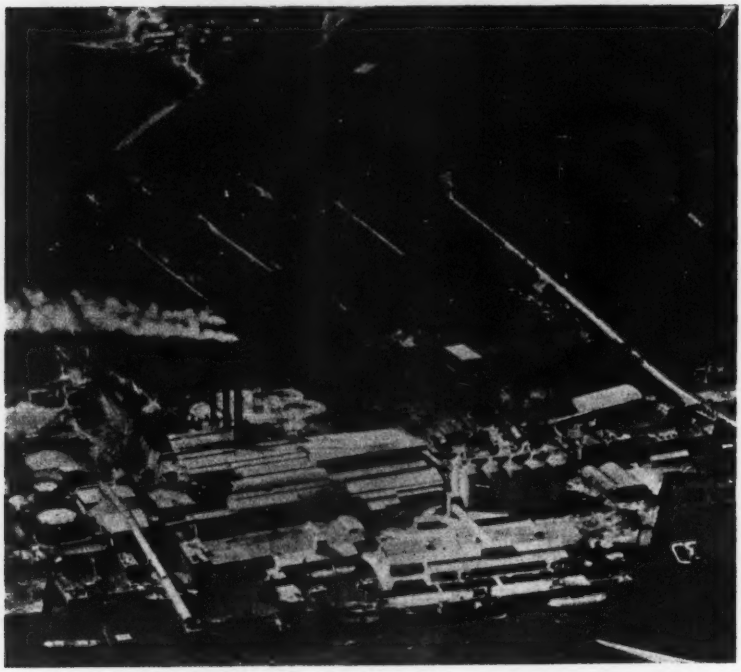
WITH this issue of "Concrete and Constructional Engineering" we publish the first number of "Cement and Cement Manufacture," which it is hoped will interest a wide circle of readers actively engaged in the manufacture, testing, and other processes in the production of Portland and aluminous cements.

It is our intention in this supplement to publish articles on the subject by the leading authorities of the day, covering every aspect of the chemistry and manufacture of cement. We also propose to give from time to time illustrated descriptions of some of the more modern and interesting cement factories, and to give early information of new machinery and plant and new methods used in the various manufacturing processes. In this number we give a description of the largest cement works in Europe—the new Bevans Works at Northfleet of the Associated Portland Cement Manufacturers, Ltd.

We have been fortunate in securing the co-operation of one of the leading experts on the subject in Great Britain to act as advisory Editor of this Supplement, together with a number of expert contributors, so that its contents will be particularly authoritative and valuable.

It is an anomaly that an industry producing more than fifty million tons of manufactured material a year should have been so poorly catered for in periodical literature, for hitherto the only periodical in the English language dealing solely with cement has been a supplement to a United States journal. In Great Britain the cement industry has had to rely upon occasional articles in various building and engineering periodicals for information on new developments which vitally affect its well-being. This gap is now filled by "Cement and Cement Manufacture," which we hope to make increasingly useful as time goes on.

Our desire is to make this Supplement as valuable as possible to our readers, and to that end we would welcome suggestions for new features that might be useful or subjects on which readers might like information. We also invite contributions for publication in "Cement and Cement Manufacture" from those connected with the industry who have useful information to impart on any phase of cement manufacture or testing.



AERIAL VIEW OF BEVANS CEMENT WORKS, NORTHFLEET, KENT.
(The largest Portland Cement Works in Europe.—See p. 21.)

Portland Cement of To-day and To-morrow.

By A. C. DAVIS, M.I.Mech.E., M.Inst.C.E.I., F.C.S.
(*Works Managing Director, Associated Portland Cement Manufacturers, Ltd.*)

THE introduction of a British journal dealing with *Cement and Cement Manufacture* is an innovation worthy of all praise and support by those who have at heart the prestige of the British cement industry, for thus we are at last saved from the reproach that the British nation, as the inventors of Portland cement, and for decades the pioneers of Portland cement manufacture over the world, have not even a cement journal to boast of.

The incongruity of such a position in the past has often been remarked upon, and emphasised, both at home and abroad, by those who come to England to visit our factories and to learn of the last word in up-to-date high-quality cement production. Foreigners wishing to make themselves conversant with the most modern steps in the advancement of the technique of British cement manufacture, which to-day leads the world in the commodity known as "British Portland Cement," have had no opportunity of studying an up-to-date periodical giving the information they require.

Is any further justification needed for the inauguration of a monthly Cement Journal? If it is, then the increasingly large number of uses to which Portland cement is applied to-day is little more than a deserved tribute to the great strides which have been made during recent years in the science of the manufacture of this invaluable product, and which tribute will, I hope, be emphasised by the innovation of this new monthly journal *Cement and Cement Manufacture*.

The debt which is owed to Portland cement to-day is certainly not recognized as widely as it should be. The use of Portland cement has rendered possible most of the architectural, and more especially engineering, feats of the past century, and with the quality of the British product of to-day the adaptability and durability of concrete far exceed that of any other constructive material.

The present excellence of Portland cement is the outcome of years of patient scientific investigation and study, and although the names of the early British inventors and perfecters of Portland cement over a century ago are forgotten, or at least but dimly remembered, the result of their work has to-day originated and assisted design to as great, or perhaps a greater, extent than has the introduction of mild steel for construction purposes.

The past five years in this country have witnessed a revolutionary improvement in the quality of Portland cement production, with the result that the manufacture of cement in the United Kingdom is now carried on under scientific chemical control, and with machinery and plant which are constantly being improved with the object of securing high quality and greater perfection and uniformity in the marketed product.

The result of these improvements in cement manufacture is that modern Portland cement, as compared with the older product, is distinguished by higher results in tensile and crushing strains, freedom from unsoundness, and an increase in sand-carrying capacity, or the ability to secure satisfactory results in concrete with a smaller proportion of cement to aggregate; while last, but not least, the

intensive rapid-hardening qualities of modern Portland cement give concrete new uses and new fields which are daily being more widely advanced.

Simultaneously with the improved manufacture of Portland cement, both theoretical and practical, every day is bringing home to us very forcibly the fact that the properties of cement for general constructive purposes are illimitable; indeed, speaking generally, its uses are unending. In almost every method of construction to-day the manufacturer sees that his endeavours to produce a more reliable quality of cement are accompanied by a gratifying increase of trade.

It is deserving of comment also that the utility of Portland cement concrete has been thoroughly realised by the majority of engineers and architects in this country; the impetus given to cement manufacture by the use of Portland cement in the chief engineering and architectural works of the present day is remarkable, for the professions have given to concrete a place of unchallenged importance.

Modern architecture and building and engineering practice demand a high-grade Portland cement possessing rapid-hardening qualities, great tensile strength, fineness of grinding, uniformity in colour, and particularly a good "brand" product, thus assuring that all constructional work will improve with age and stand sound and strong for whatever period it may be designed.

Many of the old monuments of the past that have endured for more than two thousand years were built of a concrete far inferior in quality to that which we use to-day. Still, these monuments endure, though stripped of their facings of mosaic, tile, and stone by the ravages of time and conquest. What then may we expect of the great structures which we are building to-day under the guidance of modern engineering and architecture with modern cement? It is certain that the concrete of our day will endure far beyond time, and as the professions become more acquainted with the true characteristics of the quality of the Portland cement of to-day it is only left for me to suggest that, while we have learnt thoroughly how to make concrete strong, let us now learn how to make concrete beautiful.

In your journal *Concrete and Constructional Engineering* you devote considerable space to this subject, and give valuable help and advice in furthering this idea. May the innovation of *Cement and Cement Manufacture* enlarge upon this admirable pursuit, which can only result in an inestimable benefit to all interested and concerned in this engrossing subject.

Continental Cement Agreement.

It is understood that an agreement has been concluded between the French cement producers and those of Belgium and Luxemburg regulating the sale, exportation and importation of cement and cement products in those countries. It is stated that the agreement is based on the principle of a limitation of the quantities of cement which may be exported into France by Belgium and Luxemburg, and the quantities the French producers may export into Belgium, Luxemburg and Holland. There has been no apparent fixing of prices, and the amounts of the tonnages agreed upon have not been divulged.

Since the announcement of this agreement the following new incorporations have been announced in Belgium: "Ferrociment," Marchienne-au-Pont, Belgium (capital 6,000,000 francs) to produce all forms of cement.

"Auxiliaire des Ciments," Brussels (capital 10,000,000 francs); backed by a combine of Belgian cement factories.

A new Belgian corporation is being formed to acquire control of several cement mills in Eastern Europe, with a capital of 40,000,000 francs.

CEMENT AND CEMENT MANUFACTURE
(Incorporated with "Concrete and Constructional Engineering")

Progress in the Cement Industry.

By Professor CECIL H. DESCH, F.R.S.
(University of Sheffield)

ALTHOUGH hydraulic cements were known to the Romans, and were used by them with great skill, and although the work of Smeaton towards the close of the eighteenth century laid a scientific foundation for their study, the producduction of a synthetic cement by burning together its constituents at a high temperature is only a hundred years old. Long after the manufacture of Portland cement had become an important industry the methods used were primitive from a scientific point of view. So long as stationary kilns were used to burn the clinker there was bound to be much underburnt material left in the charge, and this had to be removed as far as possible by hand picking. With that precaution, good cement was made, but it was far below the standard reached at the present day, for several reasons.

Methods of Burning.

The strength of a cement increases, other things being equal, with the proportion of lime it contains, until a certain limit is reached which is far higher than the lime content of the older Portland cements. With the stationary kiln an increase of lime means an increased danger of unsoundness, and to guard against this the lime content has to be kept low. The possibility of making a stronger cement came with the introduction of the rotary kiln. Not only does the rotary kiln allow of higher temperatures being used, so that the chemical combination of the lime, silica, and alumina is carried farther than when the temperature is low, but it is far more uniform. The nodules of clinker are alike in composition and in the temperature to which they have been raised, so that there is no underburnt material and the reaction may be carried as far as the temperature will allow. The higher the temperature the more complete the combination, and the greater the amount of lime that can be held by the cement without causing unsoundness, until the saturation value is reached. Such hard, fully burnt material is relatively inert unless finely ground.

In the old days not only had underburnt material to be removed, but it was thought that it was possible to overburn the clinker so that it would only react sluggishly with water. This was only true because of the coarse grinding of the cement. A cement is better and stronger the more completely its constituents are combined, but it has to be ground to a greater degree of fineness to bring out its good qualities.

Hence the two directions in which cements have been improved in the last twenty years or so have been the more perfect burning of the clinker and the finer grinding of the product. These two conditions have made possible improvements in the chemical composition, and have also led to a far greater uniformity of the product.

Along with the improvement of manufacturing processes there has gone a remarkable advance in our knowledge of the chemistry of cements. This has been due in large part to the fine work of the Geophysical Laboratory in Washington, undertaken in the first place without any thought of technical applica-

tion and intended only as a part of a general programme of research into the constitution of igneous rocks. Based on the early studies of Le Chatelier, the work of the American investigators has given us a clear picture of the constitution of cement clinker, and has also shown the directions in which future progress is to be sought. It is gratifying to know that since the laboratories of the Building Research Board at Garston have been opened our own country has been enabled to take a share in the scientific investigation of cements, a task which we have left too long to the exclusive attention of Continental and American workers.

Possibility of Complete Fusion.

At present it may be said that the highest qualities of Portland cement approach in chemical composition the limit of what is practicable in the rotary kiln. The materials in that kiln are sintered, but not actually fused. A still further advance would be made if we could actually reduce the mixture to a fluid state, and cast it as if it were steel. There is no indication of that step being taken as yet, the production of such a high temperature being both costly and troublesome, but it is a possibility to be borne in mind.

As far back as 1906 the late Mr. Bertram Blount suggested that the next advance in the manufacture of Portland cement would be the actual fusion of the materials, either by enriching the blast with oxygen or by using electrical heating as an auxiliary. That prophecy has not been so far fulfilled. However, the scientific investigations referred to led to the study of mixtures differing widely from Portland cement in composition. Too high a proportion of alumina had long been regarded as dangerous, especially in cement liable to be exposed to sea water, but it was found that there was a range of composition among highly aluminous mixtures which would yield sound cements if brought into complete chemical combination, which was possible on account of their relatively low melting-point.

Rapid-Hardening Portland and Aluminous Cements.

In this way there came into existence the aluminous cements, which are completely fused, either by the electric current or by high-temperature gas-firing. Such cements have the property of hardening in a few hours, giving strengths comparable with that of the best Portland cement, so that they soon became popular, especially for roads and for similar purposes for which it is essential that the concrete made from the cement shall be ready for use with the smallest possible delay. This invention gave a great impetus to research. If, by departing widely from the usual practice, such remarkable results could be obtained, was it not worth while to examine other compositions in more detail? No corresponding discovery has yet been made, but there is a range of composition which it may prove profitable to investigate.

The advent of the rapid-hardening aluminous cements also gave an impetus to the improvement of the older cements. Rapid hardening must be clearly distinguished from quick setting. The latter is a disadvantage in most work, destroying the plasticity of a mortar or concrete too soon, but the rapid attainment of full hardness is a most valuable property. It was not long before Portland cement, rivalling in that respect the fused aluminous cements, was put on the market, and the preparation of concrete which is hard and strong enough

to resist heavy loads and abrasion in 24 hours is now a common thing. The improvement has been brought about in large measure by finer grinding, which has been mentioned as the second line of advance.

Advantages of Fine Grinding.

When ground cement reacts with water, the particles are too dense to allow the water to penetrate into them, and it reacts with the surface only. Under the microscope each particle is seen to coat itself with a layer of gelatinous material, in which minute crystals gradually form. In the ordinary way this coating becomes so impervious that the water is unable to reach the core of the mass, which remains unchanged during the subsequent history of the mortar. When a fully hardened mortar is examined in a thin section under the microscope it is surprising to see how large a grain of unaltered clinker occupies the centre of each little mass of hydrated cement. Such grains are serving merely as inert material, for which sand would be equally good. Could the cement clinker be ground still finer, a higher proportion of it would be utilised, and a given quantity would go farther in making a strong mortar or concrete. It remains to be seen whether the practicable limit of fine grinding has been reached; possibly this is so with existing plant, but it may be that the technique of grinding will undergo great changes. Already, in other branches of industry still finer degrees of subdivision are becoming common, and powders of greatly increased chemical reactivity are produced. Such a fine cement would set and harden quickly, but the initial set could be controlled by additions.

This brings up a question on which there is still some uncertainty and room for research. The reactive cements are readily affected by the presence of small quantities of salts. Even the degree of alkalinity of the water used in mixing has an appreciable effect in altering the rate of setting, and although a large amount of empirical knowledge has been accumulated, so that it is not often that practical difficulties arise, yet we do not understand the action of additions at all fully, and occasionally puzzling behaviour is noticed. This is one of the problems which we look to the investigators of the present day to solve. Naturally the effect on cements of different compositions will not be the same.

Pozzolanas.

The highly basic compounds which constitute the active part of Portland cement are decomposed by water, forming the compounds which harden, and liberating lime at the same time. This lime crystallises in the gelatinous mass which makes up the matrix of the mortar during hardening, but does not contribute appreciably to its strength. It is more readily attacked by sea water, sewage, and other destructive agents than the other constituents, and in case of fire it decomposes, helping to disintegrate the concrete of which it forms a part. The Romans, who used lime mortars both for brickwork and for concrete, gave the mass the necessary resistance by mixing with it a pozzolanic material, either the fine volcanic ash which has given its name to a class, or in default of that a burnt clay in the form of ground tiles or similar material. Pozzolanas have the property of combining slowly with free lime and converting it into insoluble compounds. The same practice, applied to Portland cement, has its advantages. Increased resistance to sea water and fire is gained by mixing with a

pozzolanic material. Trass, the best known of such materials, is often insufficiently active, and finely-ground granulated blast-furnace slag of suitable composition, active silica, and certain lightly burnt clays have been used with advantage. The chemical study of pozzolanic materials needs to be carried further, as it is obviously wrong to make additions to a cement unless their action and nature are thoroughly understood.

Use of Cement.

A few words may be said as to the proper use of a cement after it has been made with all the care and skill that the manufacturer can bring to bear upon it. To develop its full strength the cement must be properly mixed and made into a compact mass with the sand and aggregate. The scientific proportioning of mortars and concretes is now recognised as essential to their efficient use, but that recognition is far from universal amongst users. Moreover, to get the best out of a mixture, it must be made as compact as possible. Resistance to destructive agents, permanence on exposure, strength and impermeability, all depend on the making of a dense mixture. There have been many speculations as to the cause of the high quality of ancient Roman mortar and concrete, many chemical additions having been suggested, but the historical and chemical evidence is against them. The writer is convinced that the secret lay simply in the very thorough mixing and ramming of the ingredients, and the highly-efficient cements of the present day deserve as much respect in their treatment as the pozzolanic mortars of the Romans.

This is a point on which manufacturers might do much to educate users. When one hears of disasters to concrete structures the explanation is usually found to be imperfect mixing or ramming, and proper attention to these matters would raise the general level of work in concrete and reinforced concrete construction. A thoroughly dense concrete is one of the most permanent materials known; a loosely-packed concrete is liable to destruction from many causes. The quality of the cements produced in this country is admirable, and the standard of workmanship in its use is also high. It is to be hoped that the industry will give encouragement to research work, so that the standard may be maintained and advantage taken of every new scientific discovery in this most important field.

United States Cement Production.

FIGURES of the production of Portland cement in the United States during the period January to May, 1928, and the corresponding period last year (in barrels) are stated to be as follows.

	1927.	1928.
Make	57,834,000	59,536,000
Shipments	55,014,000	55,531,000
Stock-in-hand, May 31	23,503,000	25,921,000
Production per cent. to capacity available during 12 months ending May 31	75·5	73·9
Production per cent. for May only	88·9	86·6
No. of plants in operation on May 31	146	157

Modern Cement and Modern Cement Testing.

By D. B. BUTLER, Assoc.M.Inst.C.E., F.C.S.

WHERE such reference is available, it is only necessary to look up records of eight or nine years ago to realise the enormous progress that has been made in the quality of Portland cement during the past few years, progress which has resulted in present-day cement being at least 50 per cent. stronger and better than pre-war material. This applies not only to the product of British factories, which it may be confidently stated have led the way in this respect, but also to that of other great cement-producing countries of Europe, the latter point being one upon which the writer, owing to an extensive foreign practice, has had unique opportunities of forming an opinion. Even the smaller cement-producing centres of Europe, as well as those of the Middle and Far East, now manufacture a quality of cement which ten years ago would have been considered exceptionally good; some of them, in fact, are equal to the best European brands.

Aluminous and Rapid-Hardening Portland Cements.

There is no doubt that the most striking innovation of modern times is the introduction of rapid-hardening Portland cement, a material which was "evolved" (if the term may be permitted as representing painstaking experiment and research) by a leading British firm of cement manufacturers some three or four years ago, and has since had many imitators both in this country and abroad. The compelling force underlying the "evolution" and development of rapid-hardening Portland cement, was the then recent introduction from France of an aluminous cement developing within one or two days a much greater strength than that of ordinary Portland cement at 28 days. In spite of its high price, i.e. nearly double that of ordinary Portland cement, the value of such a material for urgent road and street repairs and similar work where rapid service is essential, needs no emphasis, and an endeavour to produce something that would compete with this material was responsible for the evolution of rapid-hardening Portland cement.

It is well known that aluminous cement is altogether different, both in its chemical composition and method of manufacture, from Portland cement. In the first place, it is a highly aluminous, low lime-content cement, the lime and alumina content being about 42 per cent. and 40 per cent. respectively, compared with about 64 per cent. and 8 per cent. of Portland cement; in the manufacturing process, also, the raw materials are absolutely fused, and leave the kiln in a liquid molten condition, whereas with Portland cement burning is carried to incipient vitrifaction only, and if heated beyond that point the product would be altogether spoilt and useless.

It is reported that the rapid-hardening properties of aluminous cement were more or less incidental, the research which led to its production having for its original object (in which it was entirely successful) the discovery of a cement which would withstand the attack of sulphur-impregnated waters, which are fatal to the stability of Portland cement concrete. Although not introduced into this country until some time after the war, aluminous cement was produced on a somewhat limited scale some years previously, and report has it that it was in considerable demand for gun mountings and foundations by the French and allied

armies. It can be readily understood, that a material which after one or two days attained a strength and hardness equal to that of ordinary Portland cement after 28 days would be extremely useful in getting big guns into action with the least possible loss of time, and thus prove a valuable asset to the allied artillery officers.

Broadly speaking, it may be said that the object of the originators of rapid-hardening Portland cement, as regards competition with aluminous cement, has, on the whole, been quite satisfactorily attained. With the exception, perhaps, of the first 24 hours or so, there does not seem to be very much to choose between the strength and hardness of the best brands of modern rapid-hardening Portland cement and aluminous cement, and whereas the cost of aluminous cement is still nearly double that of ordinary Portland cement, the cost of rapid-hardening Portland cement is only about *7s. 6d.* per ton higher, and the difference will probably tend to become less and less as time goes on. The originators or inventors of rapid-hardening Portland cement have therefore conferred an immense boon upon the constructional world generally; it is, perhaps, betraying no secret to state that the prime mover in the evolution of rapid-hardening Portland cement was the late H. K. Bamber, a leading figure in the cement manufacturing world, and one of the writer's oldest professional friends. His untimely death in a motor smash some three years ago was an irreparable loss to the industry.

It may be mentioned here that the first rapid-hardening Portland cement brought to the writer's notice was during the war. It was a Swiss product, and the idea was to introduce it into this country, which at that time appeared to be rather a hopeless proposition owing to transport difficulties. Judging from samples submitted it possessed marked rapid-hardening properties, and also a strength far superior to the ordinary Portland cement of that day, though scarcely equal to modern rapid-hardening products.

Setting Time of Rapid-Hardening Portland Cement.

The salient feature of modern rapid-hardening Portland cement is its extremely finely-ground nature, many of the best brands leaving less than 1 per cent. of residue on a 180 × 180 mesh sieve, and it is the cost of this extremely fine grinding which is the chief reason of its enhanced price compared with that of ordinary Portland cement. According to the writer's experience the setting properties of this extremely fine material are sometimes a little peculiar. For instance, if in accordance with our usual practice, the whole operation of gauging the paste and placing it in the moulds is completed within about two minutes from the time of adding the water, the setting time, as determined by the British Standard Specification needle is, for example, 7 minutes initial, and 25 minutes final. If, however, instead of the whole operation being completed in about 2 minutes, the mass is continuously worked and trowelled for 4, or even 3, minutes before being placed in the moulds the setting time is sometimes found to be altogether different, and may be prolonged to as much as 105 minutes initial, and 4 hours final.

The question then arises, which of the two results is the true setting-time of the cement from the users' point of view, which, after all, is the real object of the test? Although some may disagree with him, the writer strongly supports the former, for the following reasons. Would there not be some considerable danger, in actual use, of such a cement stiffening and commencing to set before the con-

crete is finally placed in position, with probable loss of strength and workability? This stiffening or loss of plasticity would be a very serious matter in some instances, more particularly in heavily reinforced concrete beams, such as are used in bridge work, where the reinforcing bars are frequently so close together that they somewhat resemble a steel cage. In such cases, if the concrete had stiffened at all and was not easily workable, it would be impossible to get it properly worked in between the bars, with consequent loss of proper covering and efficiency. Instances have occurred in which the setting of such cement, after the usual two minutes' gauging and manipulation, has been quite final and definite, the mass being so stiff and hard after five or six minutes as to render it impossible to break it down again with the flat of the trowel; and yet if the manipulation has been continuous for three or four minutes, without allowing the mass to rest, the initial and final set, as previously mentioned, have been well within the British Standard Specification requirements for normal-setting cement.

Having regard, therefore, to the widely divergent results obtainable, and their important bearing from a practical point of view, this question of the time to be occupied in working and trowelling in setting-time and other tests is one that might be taken up with advantage by the British Engineering Standards Association.

Need for Standard Specification.

In view of the enormous developments in the production and use of rapid-hardening cement during the past two or three years, a British Standard Specification for that material is badly wanted; in this respect we are considerably behind other European countries, notably Belgium, where an official specification has been in force for twelve months or more. In Belgium, however, Portland cement is divided into three classes or categories, i.e. "Normal Artificial Portland Cement," "High Strength Artificial Portland Cement," and "Rapid-Hardening Portland Cement." A separate Specification is issued for each category as regards fineness and strength, but the tests for setting time, soundness, etc., are common to all three. The most striking feature of these specifications is the low standard required as regards fineness of grinding compared with the English practice, the maximum allowed on a sieve of 4,900 meshes per square centimetre, which is approximately the same as our English 180 × 180 sieve, being as great as 18, 14 and 10 per cent. respectively for the three categories in question. It is difficult to imagine a rapid-hardening cement so coarsely ground as to leave 10 per cent. residue on the 180 sieve, and it is only fair to state that nearly all the Belgian rapid-hardening cements which have passed through our laboratory during the past year or two have been ground to nearer 1 per cent. than 10 per cent. residue on that sieve.

The only English specification for rapid-hardening Portland cement the writer has so far met with is that of a leading reinforced concrete consultant, which stipulates a minimum 1, 3 and 7 days' tensile test of 3 : 1 sand-cement mortar of 300, 400, and 600 lbs. respectively. Although many of the rapid-hardening cements of the present day considerably exceed these figures, more especially after 24 hours, the above-mentioned minima are quite fair and reasonable, at all events for the present, and no difficulty should be experienced in complying with these requirements.

Rapid-hardening Portland cement would, however, appear to be of a some-

what more delicate constitution, if the phrase may be permitted, than ordinary Portland cement, its older brother, and to be more easily affected by atmospheric influences, both in its powder condition and the initial stages of hardening. At all events, much greater care and attention to details appear to be necessary, both in the preparation of the briquettes for testing and in their subsequent treatment, more especially with the 24-hours' test. Very small differences in the temperature and humidity of the atmosphere in which the briquettes are gauged and subsequently cured appear to make a very considerable difference in the strength developed. To obtain the best results care has to be taken that the atmosphere in which they are cured is saturated with humidity, and also that it is not allowed to fall below 62 degrees Fahr.

The question has been raised as to whether these briquettes should be "cured" entirely in moist air for the whole 24 hours between moulding and testing, or whether they should be removed from the moulds and placed under water for the last five or six hours. The latter treatment is claimed by some as more nearly approaching the current British Standard Specification conditions for Portland cement, but, as before mentioned, rapid-hardening cement appears to possess setting properties so different in many respects from those of ordinary Portland cement that special methods of manipulation and treatment would seem to be necessary. In order to eliminate the personal equation as far as possible, and to produce more concordant results by different operators, all these points require to be very carefully considered and laid down in a special specification. In addition to the percentage of water used being definitely fixed, there should be a limit as to the time occupied in mixing and gauging and also as to the amount of beating and packing into the moulds. It should not be possible, as has recently occurred, for the laboratories of two London experts to obtain results differing by as much as 55 per cent. from one and the same sample of rapid-hardening cement submitted to them at the same time.

Effect of Cement on Health.

A STRIKING commentary on the healthy nature of work in cement factories is given in a report on occupational mortality, issued by the Registrar-General, based on the 1921 Census. Taking the average mortality rate for all males aged 20–65 as 1,000, the report quotes the following individual occupations with exceptionally high or exceptionally low mortality, from which it will be seen that the inhalation of cement has no injurious effect.

	Mortality Rate.
Agricultural labourers, etc.	688
Cement workers, lime burners, etc.	717
Carpenters	843
Platelayers	920
Gamekeepers	667
Potters, etc.	1,642
File cutters	1,851
Cutlery grinders	3,295

On this question, a German doctor has issued a report on the effect of cement dust upon the human lung and the problem of tuberculosis among cement workers. He states: "Even decades spent in cement plants bring about no lung trouble harmful to human life. We can state with certainty that employment in cement plants does not in itself carry any danger of tubercular trouble. On the contrary, tuberculosis shows a satisfactory course in cement plants."

It is stated that a physician has actually prescribed a special powder for tuberculosis patients to inhale, such powder being composed of 70 per cent. lime, 10 per cent. silica, 15 per cent. carbon, and 5 per cent. iron oxide and alumina.

The Testing of Portland Cement.

By R. H. HARRY STANGER, A.M.Inst.C.E., A.M.I.Mech.E., F.C.S.

It is not the intention of this note to discuss the reasons for the testing of Portland cements, as the necessity for the control of the manufacture by the laboratory will be admitted by everyone, whether he be manufacturer or user; rather would I draw attention to such improvements in the methods of routine testing as appear to me to be really necessary.

The usual tests to which Portland cements are submitted are :—

(*a*) Chemical analysis.
(*b*) Physical tests.
  (1) Setting time.
  (2) Soundness.
  (3) Strength in tension and (or) compression.
  (4) Fineness.

Chemical Analysis.

There is much divergence in the details of the methods of analysis to be adopted when working to the many specifications at present in use in various countries. The British Standard Specification is one of those which refrain from specifying any methods.

Most cement chemists have well-tried methods of their own, probably only differing from one another in minor details which they find suit their style of working and produce satisfactory results closely agreeing with the results of others. Improvements in this part of the work are, therefore, unlikely except in certain small points; for instance, I find it distinctly preferable to substitute electrically-heated hot-plates in place of the usual gas-heated ones. In the ignition of precipitates, however, the gas-fired muffle is more advantageous as the temperature necessary is just outside that safely obtained with the present commercial electrically-heated muffle.

Physical Tests.

Water Content.—It will be agreed that all physical tests, with the exception of that for fineness, are dependent on the quantity of water used in gauging and on the skill of the operator, and it is in the direction of controlling the former and standardising the work of the latter that, in my opinion, the greatest improvement is likely to take place.

Amongst the countries issuing standard specifications I believe our own and Germany are the only ones in which the quantity of water to be used in gauging the neat paste is left to the judgment of the operator. In the case of the B.E.S.A. Specification the only guide given is that the mixture shall be plastic when filled into the moulds. Experiments have, however, shown that expert gaugers in different laboratories can differ in their opinion of the necessary quantity to achieve this end by as much as 3½ per cent.—20½ per cent. to 24 per cent. for a particular cement. As the quantity of water used in gauging the mortar tensile briquettes is determined by formula based on the amount considered necessary for the neat paste, it will be evident that an im-

proper decision in the first place on the part of the gauger will have considerable effect on other tests.

In all other countries the quantity of water necessary for the neat paste —in other words, the normal consistency of the cement—is ascertained by tests along definite lines, the Vicat apparatus involving the use of a plunger of standard area being almost universally adopted. Differences, however, are to be found in the various standard specifications so far as they relate to the depth to which the plunger shall sink and the time in which the specified depth shall be reached. Still, the method does give a certain uniformity and I foresee the time when a definite move in some such direction will be made in this country.

Gauging.—While the use of such an instrument undoubtedly assists in obtaining closer working between different operators, the actual gauging of the paste may lead to widely varying results unless this part of the work, as expressed by time and energy both in the gauging and the filling into moulds, is also controlled. It seems desirable, therefore, to find a method of mixing by mechanical means the paste of neat cement to be used for the determination of the normal consistency, and a means whereby the mould can be mechanically filled. If this can be done a very real advance will have been gained towards uniformity, and the personal equation will have been eliminated from the test, which is after all mainly required to determine a figure on which all other physical tests of gauged cement or mortar are based.

So far as the actual gauging is concerned I see no necessity for this being done mechanically when preparing the paste or mortar for the tensile or compression tests. The expert operator is highly skilled in the manipulation of his trowels, and careful experiments have often proved that his manual gauging gives no more variation than machine mixing. Two of the tests always called for, that for determining the setting time and the test for soundness, could, however, be carried out when the normal consistency is being ascertained, but this would necessitate an alteration in the specification as at present the cement for the soundness test has to be aerated for 24 hours before gauging. As the setting time is determined on the neat paste confined within the same shape mould as is used for finding the normal consistency, it seems fairly obvious that this test will be proceeded with at once, using the machine mixed paste that has been found to satisfy the requirements for normal consistency. Again, it should not be difficult to mix at the same time sufficient cement paste to leave enough over for filling the mould for the " Le Chatelier " soundness test.

Filling Moulds.—While I do not expect to find mechanical mixing employed in this country for the preparation of the tensile and compression specimens, I do look forward to some means of mechanically filling the moulds, as very great differences undoubtedly occur in this operation. Presumably tensile tests of the neat paste will rarely be called for in a few years' time, and one need only consider the work of filling the moulds with the standard mortar at present.

The B.E.S.A. Standard Specification states that the mixture shall be patted down into the mould using the flat of the standard spatula only, and that no ramming or hammering and no other instrument or apparatus is to be used. According to the dictionary I find that " to pat " is to " strike gently with the

open hand or other flat surface." While cement manufacturers and testers in this country have always accepted the wording of the specification, it will, I think, be admitted by all of them that there is nothing gentle in the actual use of the spatula when filling the mortar briquette moulds. The mortar is certainly not rammed into the moulds, but it is compacted by a number of short sharp blows with the flat of the spatula used in the same way as a hammer. In my own laboratory each mortar briquette is given a standard number of blows, and I have no doubt that each gauger in other laboratories also works to some standard of his own.

Surely it would lead to greater uniformity amongst testers if this work of compacting were to be done in a machine? Is it not simpler to specify that each mortar briquette shall receive a definite number of blows from a standard weight falling from a standard height than to say that the mixture is to be patted down until water appears on the surface, or, to take the U.S.A. specification, that the mortar shall be pressed in firmly with the thumbs, the pressure to be such that the simultaneous application of both thumbs will register a pressure of between 15 and 20 lbs.? I have not quoted the particular clauses from either specification in full, but sufficiently to show that far too much is left to the discretion of the individual.

There are several well-known types of hammer machines for compacting the mortar in the moulds, and it is to be hoped that it will not be long before some such method is made standard in this country thus eliminating a variable which exercises great influence on the results.

Strength Tests.—Why do we in this country pin so much faith to the tensile strength of the neat cement? There is undoubtedly a strong movement in the direction of doing away with this test and substituting the compression test of the mortar. When this becomes standard, and it cannot be long delayed, the compacting of the moulds should be by mechanical means.

Shape of Specimens.—As regards the shapes of specimens for strength determination, it is probable that the shape of the tensile briquette will need alteration. Professor Coker's invaluable experiments have shown that the present shape gives a false indication of the true strength of the material. Further information must, however, be forthcoming before a definite alteration can be made. For the compression tests of the mortar it is probable that cubes will be preferred to prisms or cylinders as being somewhat easier to handle in the testing machine.

Fineness.—The modern cement is so finely ground that it seems unnecessary to require the fineness on a 76 × 76 mesh sieve to be determined, and this sieve is likely to fall into disuse. With hand sieving expert operators can be relied upon to obtain concordant results, but the time taken in sieving 100 grammes through a 180 × 180 mesh sieve could be more usefully employed if mechanical sieving could be adopted. There are several makes of these machines and their use is sure to be gradually extended. This tendency of grinding cements ever finer and finer will soon make it necessary to find some other means of determining the fineness. What is wanted is knowledge of the flour content in a cement, that impalpable powder which, in the main, gives the material its property of setting and hardening. No amount of sieving will determine the real flour content; some process of elutriation is almost bound to be required.

In conclusion, I would not have it thought that I expect the work of the future cement laboratory to be entirely mechanised; this is not necessary or even desirable, but some basic or fundamental operations must be made entirely independent of the human element before concordant results, as between one laboratory and another, are obtainable with certainty.

Book Review.

"The Industrial Uses of Bauxite." By N. V. S. Knibbs.
London: Ernest Benn, Ltd. Price 21s. net. pp. vi + 141.

ALTHOUGH bauxite as a mineral was discovered a century ago it is only during the past twenty years that it has become known, even to geologists, and its rise to a position of prime importance in the industrial world during the last few years has been phenomenal. The chief reason for this is the use of bauxite as the raw material for the production of the metal aluminium which has lately come into great demand for aeroplane and motor car construction; but the discovery of aluminous cement, which depends upon bauxite for its manufacture, and the application of bauxite to oil-refining have also combined to add to the general interest in the mineral and to stimulate the search for its deposits. The volume under review gives a somewhat brief summary of the technical literature dealing with the origin, occurrence, and uses of bauxite, but some hundreds of references to the original sources of information are given by the author and these constitute a valuable record for the student of the subject.

The discussion of the various theories to account for the formation of bauxite in the earth's crust makes an interesting chapter; purely chemical explanations of the formation are not entirely satisfying, and there is more than a suspicion that micro-organisms have been responsible for the production of this remarkable ore. Bauxite is found in every part of the world, but the deposits of practical importance, i.e. in large quantities and with easy transport, are few; there was indeed a suggestion a few years ago that bauxite could be "cornered," but further activities of prospectors have shown that the deposits are too large for this to happen. The British Isles do not contain any significant quantities of sufficiently pure bauxite, and the European industries of metallic aluminium and aluminous cement production are practically dependent upon the deposits near the north Mediterranean coast in France and Jugo-Slavia. It is for this reason that aluminous cement made in England will always be a comparatively high-priced material.

The author estimates that the bauxite used in Europe and America for aluminous cement production exceeded 200,000 tons in 1926. This is equivalent to about 250,000 tons of cement and compares with a production of about 50 million tons of Portland cement per annum in the same countries, so that the restrictive effect of price upon a cement of remarkable qualities is clearly revealed.

The chemical and physical properties of bauxite are described and the methods of production of aluminium, aluminous cement, firebricks, etc., from bauxite are briefly explained. In the case of aluminous cement, the author is handicapped by the secrecy maintained by the few manufacturers of aluminous cement, and can therefore only speak of general principles. The multitude of patents concerning the production of aluminous cement to be found in every country have tended to mystify the position, and although master patents now exist in few, if any, countries, no one would embark upon the manufacture of aluminous cement without a considerable amount of investigation or the purchase of information from existing manufacturers.

The production of firebricks from bauxite, although not yet an important industry, has been of great value to Portland cement manufacturers because bauxite bricks are particularly useful in rotary cement kilns producing rapid-hardening cements, and the author has given information which should help British brick-makers to supply a demand which hitherto could only be supplied from abroad.

A Modern European Cement Plant.

FABRIK PORTLAND CEMENTU "GRODZIEC."

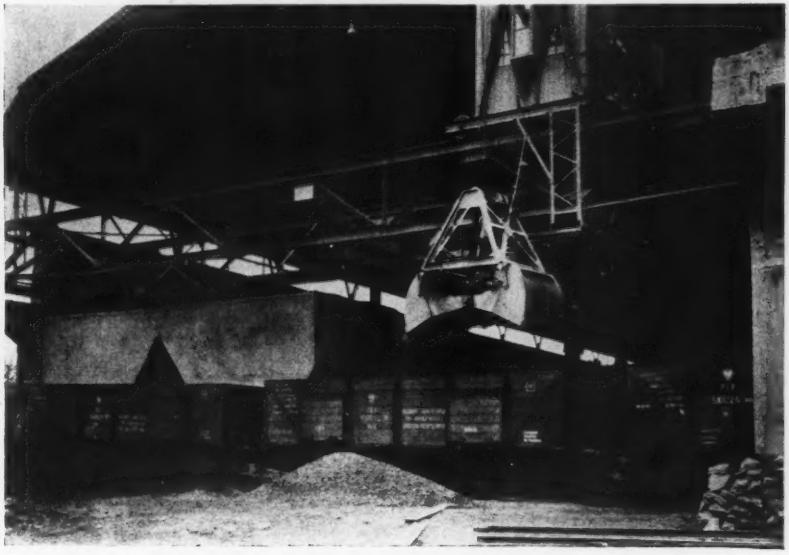
As a consequence of increased labour and fuel costs the cement industry throughout the world has undergone very considerable changes during the last few years.

A striking example of this is the Zaklady Solvay w. Polsce T.z.O.P. Cement Works at Warsaw. This works was built in 1910, when it had an output of 1,050 tons per week. During 1925 the plant was extended with a new unit having an output of 1,400 tons per week, and in 1927 a third unit was installed bringing the output up to nearly 4,000 tons per week. As soon as the last-mentioned unit was in operation, a fourth and still larger unit was decided upon, which makes the total output of the plant 5,600 tons per week. The original plant and the various extensions have been designed by Messrs. F. L. Smidth & Co. A/S., Copenhagen, who have also supplied all the machinery installed.

As the "Grodziec" Works is one of the most modern cement works in Central Europe, a brief description of the plant will no doubt be of interest to the readers of "Cement and Cement Manufacture."

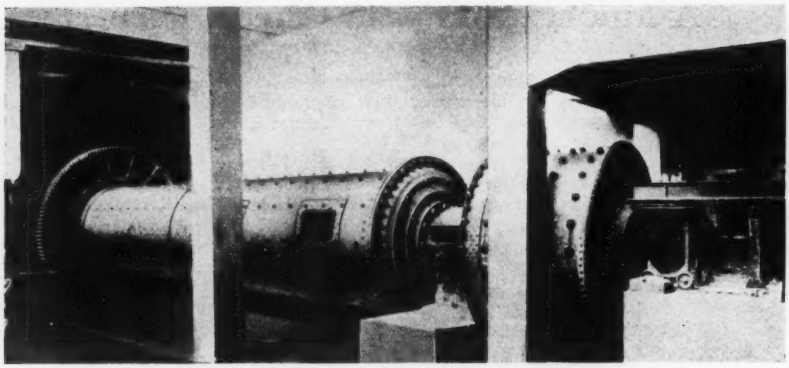
Handling Raw Materials.

The raw materials used consist of a hard limestone and marl. Both materials are conveyed to the works by rail. At the works the raw materials are tipped on to an apron feeder before entering a large roll jaw crusher. From the latter they are conveyed by means of an inclined belt-conveyor to two roller mills, and from these by another inclined belt-conveyor to a large storage building 300 ft. in length by about 70 ft. wide. The same building is utilised for storage of clinker, coal, and gypsum, and is served by two travelling cranes.



Raw Material and Clinker Store.

All the different departments of the plant are arranged in such a way that the feed end is inside the storage building, and therefore practically all the handling of

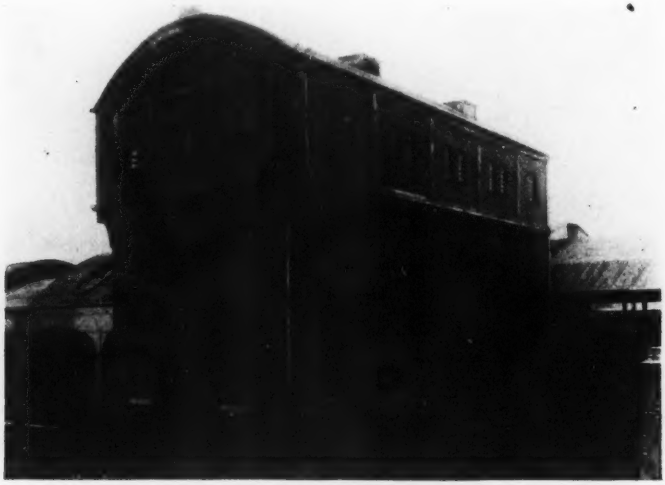


Wet Mill with Overhung Primary Chamber.

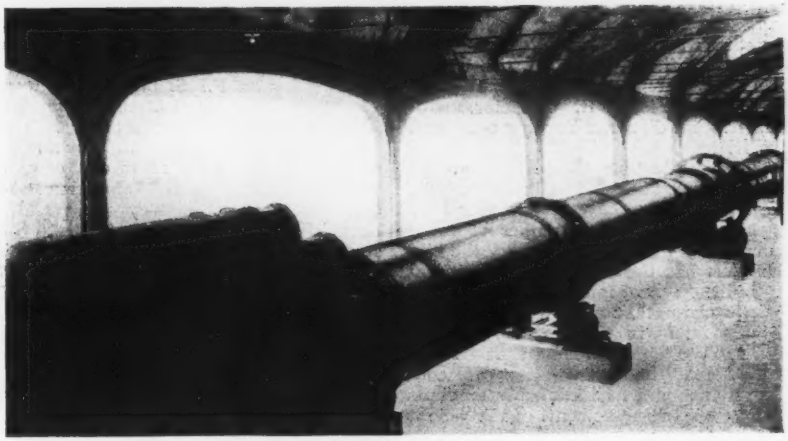
the materials is done by the travelling cranes.

The raw mill comprises two large Unidan mills, but in this particular plant a novel feature has been introduced in that the mills, which rest on trunnions, are provided with an overhung primary chamber, as shown on the accompanying illustration. This arrangement, which is patented in most countries, not only increases the grinding efficiency of the mills but makes it possible to construct mills supported on trunnions of a considerably greater length than usual, on account of the reduced moment of bending between the two supports.

From the mills the slurry is conveyed by means of two slow-running F.L.S. elevators with central discharge to the top of eleven slurry tanks used for correction



Slurry Storage.

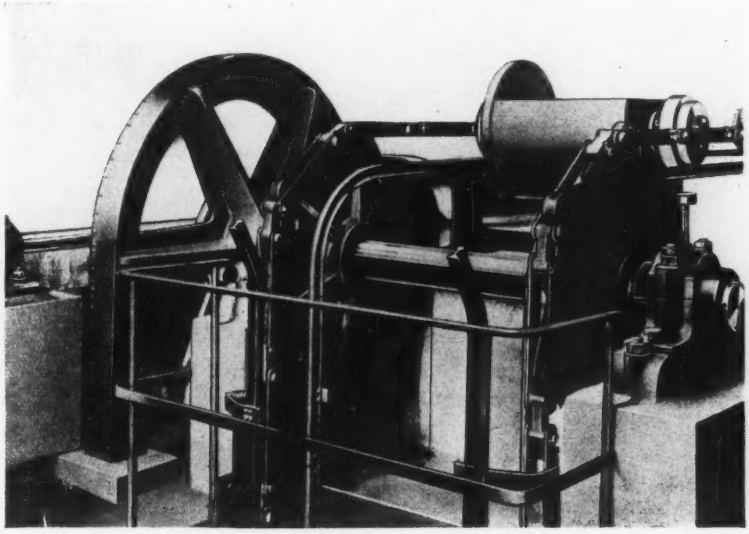


"Unax" Kiln.

and storage, the tanks being agitated by means of compressed air. As will be noticed from the illustration, the tanks are hexagonal in shape, their total capacity amounting to about 5,000 tons.

Cement Burning.

From the slurry storage the slurry is elevated by a slurry elevator to a feeding device arranged above the kilns. The original kiln is about 9 ft. in diameter



Bucket Conveyor Transporting Clinker and Gypsum.

with a 10-ft. diameter burning zone, and is 170 ft. long. It is provided with a separate clinker cooler. Nos. 2 and 3 kilns are 8 ft. in diameter, with a 9-ft. diameter burning zone, and 257 ft. long. Kiln No. 4 is 9 ft. diameter, with a 10 ft. 3 in. diameter burning zone, and 290 ft. long.

The three last-mentioned kilns are all of the Unax type. As will be seen from the illustration, the cooler in this type of kiln consists of a number of tubes mounted on the discharge end of the kiln shell. It has the advantage that it can be built on low foundations, and the makers claim that a better economy is obtained than in the ordinary type of cooler. We understand that where normal conditions prevail the coal consumption in a Unax kiln only amounts to from 22 to 24 per cent. of the weight of the clinker.

Clinker Grinding.

From the outlets of the clinker cooler the clinker is conveyed to the storage building by an F.L.S. bucket-conveyor. The same conveyor also passes over the feed hoppers for the cement mills. The conveyor is automatic, and is arranged in such a manner that it can convey various materials at the same time. It can, for instance, convey the freshly-burnt clinker and discharge this into the store, at the same time extracting stored clinker and conveying this to the mills. It can also convey a mixture of, say, 50 per cent. of each to the mill hoppers, and at the same time convey the gypsum from the store to the gypsum hoppers.

The cement mills consist of two Unidan mills, similar to those installed in a number of works in this country.

The Late Edmund Wright Brooks.

ONE of the early manufacturers of Portland cement passed away on June 22 last in the person of Mr. E. W. Brooks, J.P., which took place at Grays, Essex. Mr. Brooks, who was in his 93rd year, had been intimately connected with the industry since 1871, when he started the works of Brooks, Shoobridge & Co., at Grays. Some years later his Company was amalgamated with Messrs. Hilton Anderson & Co. In 1900 the Associated Portland Cement Manufacturers, Ltd., acquired the business, and from that time until 1920, when he retired, Mr. Brooks was a Managing Director and, for a time, Vice-Chairman of that Company.

Notes from Abroad.

German Cement Production.

THE German Zement-Bund has published its total sales for May, 1928, at 755,000 tons, which compares with 777,000 tons for the corresponding month last year. The sales for January to May, 1928, were 2,939,000 tons, compared with 2,872,000 tons for the period January to May, 1927.

Norwegian Cement Merger.

IT is reported that the A. S. Dalen Portland Cementfabrik is taking over the Cementfabrik Norge, Ce-No A.S., whose works, with an annual capacity of 75,000 tons, are situated at Dramen, 35 miles from Oslo. The Company will apparently retain its own identity.

Cement Production in Poland.

THE production of Portland cement in Poland for January and February, 1928, was 79,363 tons, against 68,673 tons for the first two months of 1927.

New Swiss Cement Companies.

A NEW cement works is proposed at Brugg, Switzerland. The capital of the Company will be 1¼ million francs (£50,000).

"Société pour Articles de Ciment" is the title of a new Company formed with Belgian and Swiss cement capital, with a capital of 10,000,000 francs (£400,000)

Bevans Cement Works, Northfleet.

THE Bevans Works of the Associated Portland Cement Manufacturers, Ltd., at Northfleet, Kent, have recently been reconstructed and enlarged, and are now claimed to be the largest and most up-to-date cement works in Europe. The capacity is stated to be about half-a-million tons of cement a year.

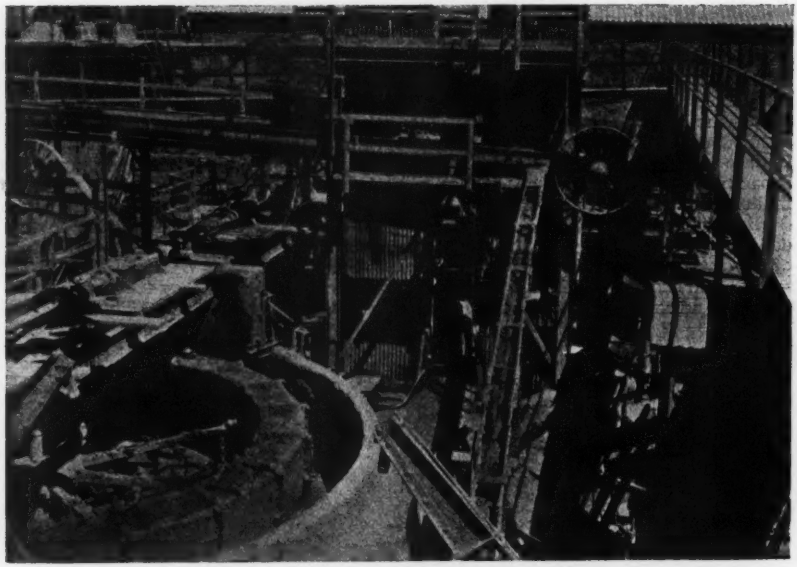
Historically, the works date back to the dawn of the cement age, in the first half of the last century, when Joseph Aspdin's son erected his first kiln on a portion of the site, and some of the original kilns are still preserved. It is not the present intention, however, to review the history of the works, but rather to describe it as it is to-day.

The geographical advantages of its position are exceptional. Situated on the great Thames Waterway with solid chalk foundations down to deep water, it has shipping facilties of a unique character.

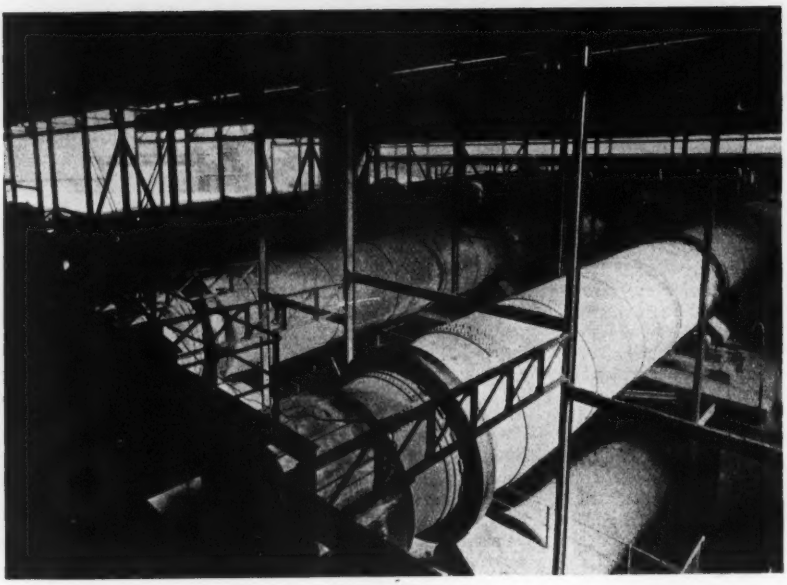
Those who are familiar with the geology of Kent know the almost inexhaustible supplies of chalk and clay which abound in this neighbourhood, and it is not surprising to learn that the Bevans management are free of all worry as to future supplies of the necessary raw materials. The clay now being used is dug by steam navvy from a deposit of London clay about two miles away, and is immediately tipped into washmills and reduced to a thin slurry with about 60 per cent. of water. This fluid clay is then pumped to storage tanks at the washmill, which is in the chalk quarry about half-way to the works. Here the chalk is dug by an electrically-operated navvy weighing 70 tons, which digs 3½ cubic yards of chalk at one bite and deposits it in 10-ton railway wagons, trains of which are hauled by steam locomotives a short distance to a combined electric hoist and tippler which picks them up bodily and tips their contents into the first of a series of heavy washmills.

In the Quarry.

The required proportion of clay slurry is pumped into the same mill from the storage tanks adjoining, and the two materials are then mechanically mixed while the chalk is being reduced to a very fine state of subdivision by the revolving harrows in the washmill. The resulting mixture of chalk and clay slurry contains about 40 per cent. of water and leaves the first washmill when it is fine enough to pass through the surrounding screens,



One of the Washmills.



The Kilns.

passing in succession through three other mills, each of which has finer screens than its predecessor. The slurry when it leaves the final mills goes to mixing and storage tanks adjoining where its composition is again checked.

It is pumped nearly a mile through two pipe-lines to the final series of storage tanks at the works. These tanks, of which there are six, are situated immediately at the upper end of the rotary kilns, and the slurry gravitates from them to the boots of the four bucket elevators which deliver it at sufficient height to enable a gravity feed to the rotary kilns. The slurry storage and mixing tanks are of standard type throughout, 66 ft. in diameter and 11 ft. deep, and are continuously agitated.

Raw Material Arriving at the Wash Mill.

The coal used by the works is all seaborne and is received alongside the eastern extremity of the deep-water jetty, where it is unloaded by electric grab cranes and transported by a belt conveyor system to storage bunkers ashore, situated at the east end of the kiln house. A complete system of extractors beneath the bunkers facilitates the isolation or mixing of fuels as the exigencies of service demand. The pulverised fuel for kiln firing is prepared by six large high-speed vertical mills housed between the coal storage bunkers and the kiln plant.

The powdered fuel is stored in self-trimming hoppers, from which it is continuously circulated along the firing floor, surplus being returned to the storage hoppers. Variable speed extractors tap the coal supply opposite each kiln at the firing end.

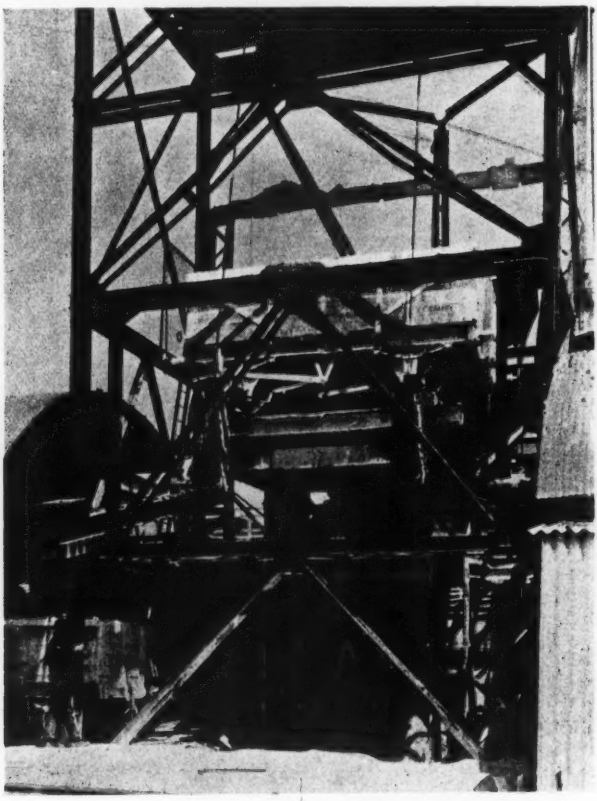
There are four rotary kilns of the latest design and construction, the loaded weight of each unit being in the region of 800 tons. Three of them are 250 ft. long with separate coolers; the fourth is 294 ft. long, and embodies a combined cooler arrangement consisting of a series of small tubes arranged around the periphery of the firing end of the kiln. All have enlarged burning zones and are direct driven through gearing from the motor to the girth ring.

The cooled clinker from the kilns is conveyed by band conveyors and bucket elevators to large reinforced concrete storage hoppers, whence it is delivered by gravity to the grinding mills immediately beneath. These mills are of the

"combination" type, consisting of a long steel tube 36 ft. long by 7 ft. in diameter, divided into compartments.

The first compartment into which the clinker is delivered is charged with steel balls of 4 in. to 2½ in. diameter. The coarse grit from this compartment passes through a slotted diaphragm into an intermediate compartment, where it is further reduced by balls of 2½ in. to 1½ in. diameter, and then passes to the final stage, where it is reduced to an impalpable powder by smaller grinding media. There are seven of these large mills, five of which are driven by slow speed synchronous motors each taking 750 h.p. and the remaining two being driven through double helical gearing and are rated at 525 h.p.

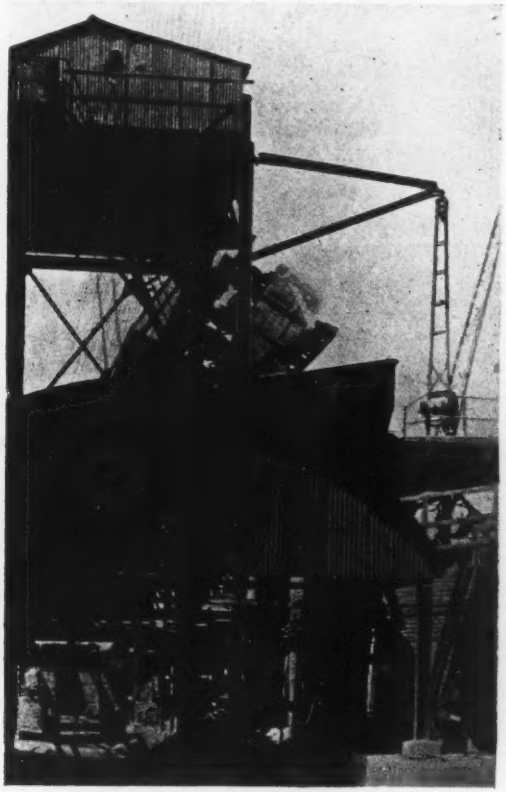
The cement is then delivered to a Fuller Kinyon pumping installation, which delivers it by means of compressed air into the battery of twelve storage silos, the lift being no less than 102 ft. This method of conveying cement is quite new to this country and a description of the installation may be of interest. The pump itself is a very simple piece of apparatus, consisting of a cylindrical barrel in which a motor-driven screw rotates at fairly high speed. Near one end the cement is admitted into the barrel, and the screw conveys the material forward. It may be noted that the pitch



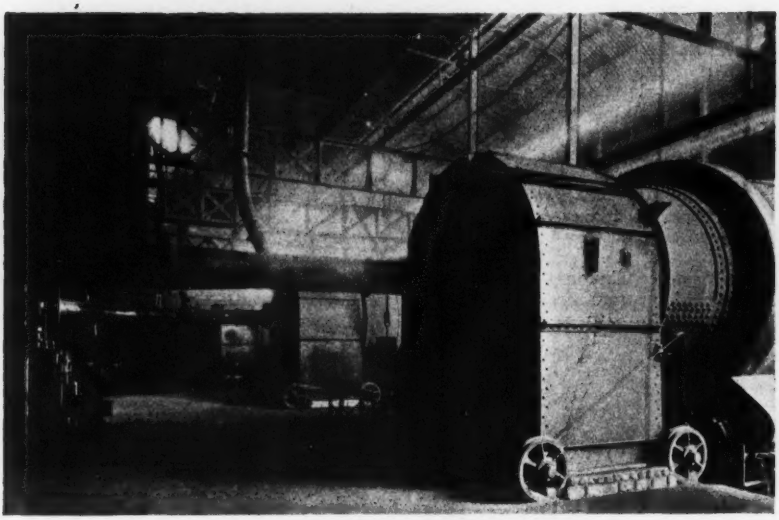
Electric Tippler at Wash Mill (Front View).

of the screw is diminishing, hence the cement fills the barrel as a piston towards the end of the screw. At the end of the barrel is a ring with an annular space (between the ring and the cylinder walls) through which numerous small holes or ports are drilled at an angle of 45 degrees towards the direction of flow. Compressed air is applied at this point, and so maintains the velocity of a stream of air (and cement) towards the open end of the pipe system. The cement is mixed with air, and the transmission of the "fluid" is continuous, but over and above the continuous stream there are more-or-less regular periodic "gusts." The lift is not accomplished by alternate layers or pistons of cement and air, as many conjecture. Perhaps the most accurate picture of the rising main would be to visualise two centrifugal pumps putting two classes of liquid through the same discharge pipe, one (say) heavy oil or tar, and the other water; both would emerge continuously with occasional gusts of the heavier fluid. If the gust were regular the analogy would be complete.

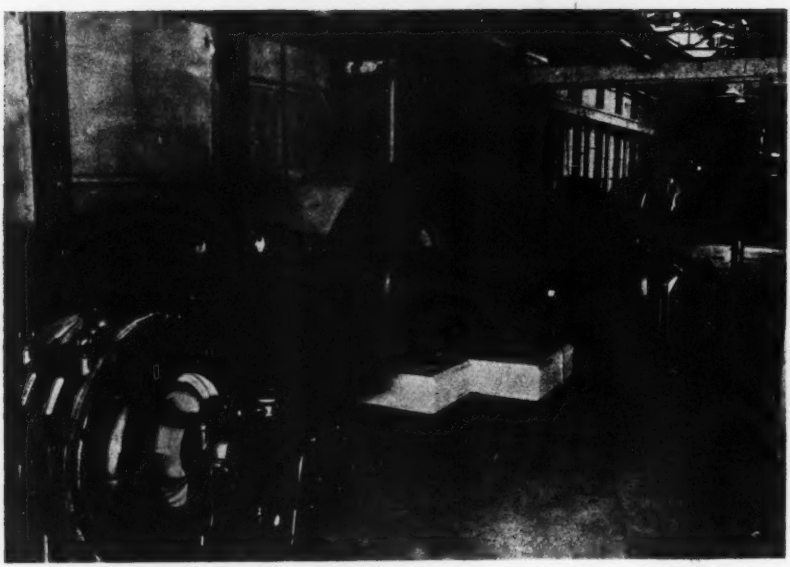
A wharf is provided for the reception of steamers discharging gypsum for slowing the set of the cement at the west end of the river frontage; after unloading, the material is conveyed by an elevated belt conveyor system to unit hoppers con-



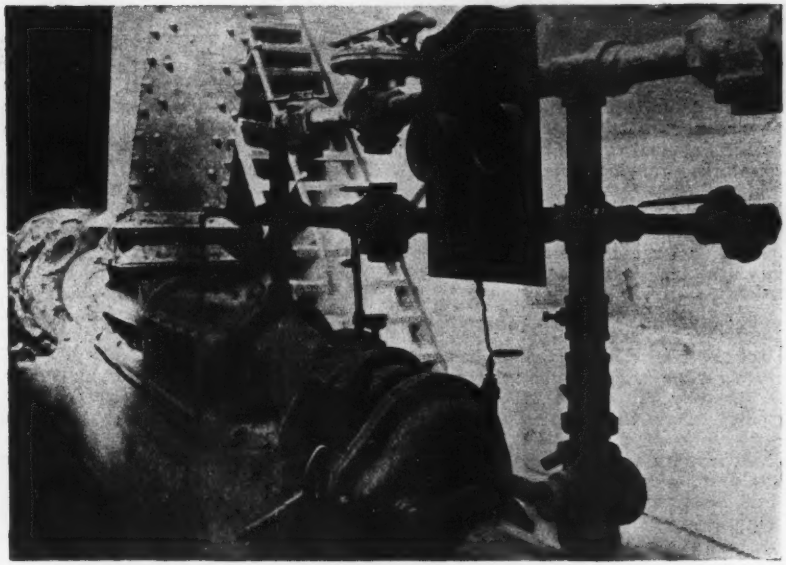
Electric Tippler at Wash Mill (Side View).



Firing End of Kilns.



Grinding Mill Motors.



Cement Pump.

structed in the clinker store immediately over each combination mill.

The twelve cement storage silos are built of reinforced concrete and are capable of holding 22,000 tons of cement. They are subdivided with central stairways to facilitate accurate sampling of the bulk.

The cement handling and packing plant and the wharf facilities at this works are exceptionally interesting, and it is proposed therefore to describe them in some detail.

The main scheme consists of a deep-water concrete jetty some 600 ft. long and capable of berthing the largest steamers (up to 15,000 tons) at all states of the tide, flanked by several unit packing plants each independently fed and operated. The jetty itself stands away from the plant, thus giving outside and inside accommodation for craft, and is equipped with five high-speed heavy duty electric luffing cranes. These cranes travel along the jetty as required and can take slings of cement from the shore plant and deliver it straight into the steamer's hold.

Adjacent plants feed the jetty by means of a circular railway track, thus supplementing the plants immediately facing the jetty. By this means a very high rate of loading can be maintained. When it is considered that some 10,000 tons of cement have to be dispatched each week, and occasionally as much as 12,000 tons, in spite of rain, fog, and other delays incidental to shipping, the necessity for such elaborate plant and organisation will be appreciated. Several complete and independent systems exist for extracting cement from the silos and conveying it to the various packing plants.

Ancillary to the factory proper there is a complete organisation of cooperages, steel-drum factory and sack plant, which supply the many thousands of packages required each day for the large tonnages shipped overside.

Special attention has been given to the important question of continuously sampling the product at all stages of manufacture.

Electric power for motive purposes is obtained in bulk from Barking, at a pressure of 33,000 volts, 3-phase, alternating current. It is stepped down to 3,000

volts at the main receiving station. As a general rule all motors of 100 h.p. and upwards are on the 3,000-volt circuit, smaller units are fed from a 500-volt distribution. Precautions are taken in the switching on and off of the larger units to preserve an even load factor, as there are some four hundred electric motors in the works ranging up to 750 h.p. each.

A complete organisation exists for "Safety First" welfare, and recreation, including a large club, swimming baths and a sports ground adjacent to the works.

Electrical Equipment.

The electrical plant as a whole has one or two notable characteristics; the motors are generally of the squirrel-cage type driving, where the starting conditions are heavy, through centrifugal clutches. All motors, including those for the tube mills, are mounted on roller or ball bearings. The cable system is totally enclosed right up to the points of application, and the smaller wiring (lighting, etc.) is in conduit, with ironclad switches and fuses, reducing risks of failure and shock to a minimum.

The power for the works is transmitted from Barking at 33,000 volts by means of underground cables, and is delivered at the supply company's sub-station at the washmills. The supply is controlled by six "K" type switches, with a breaking capacity of ¾ million kVA each, and passes on to two banks of three single-phase transformers of 2,500 kVA capacity each, i.e. two 7,500-kVA groups, which step the pressure down to 3,000 volts. These transformers are situated between the supply company's sub-station and the works receiving sub-station. In the latter are situated the power company's 3,000-volt controls witches, also of "K" class, and on which is accommodated the metering equipment. The bus-bars from these two switches are continued and connected to ten sets of truck-type gear, the switches in which have each a rupturing capacity of 100,000 kVA. This switchboard controls two feeders to the washmill sub-station, six feeders to the main works sub-station, one clay mill feeder, and one metering panel.

(To be continued)

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